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Search for new physics in π^0 and η decays with WASA-at-COSY

WASA-at-COSY Collaboration

A. Kupsc, Uppsala University

- $\pi^0 \rightarrow \gamma e^+ e^-$ (dark photon search)
- $\pi^0 \rightarrow e^+ e^-$
- $\eta \rightarrow e^+ e^-$
- $\eta \rightarrow \pi^+ \pi^- e^+ e^-$ (CP test)



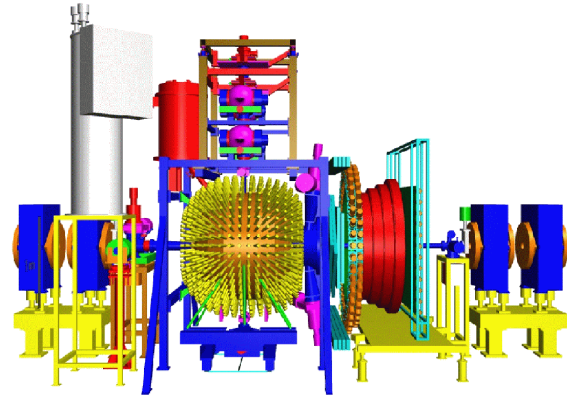
DISCRETE 2012 - Third Symposium on Prospects in the Physics of Discrete Symmetries



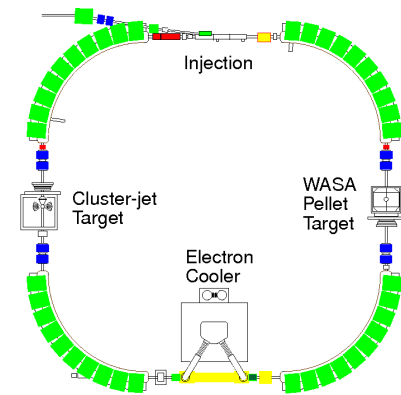
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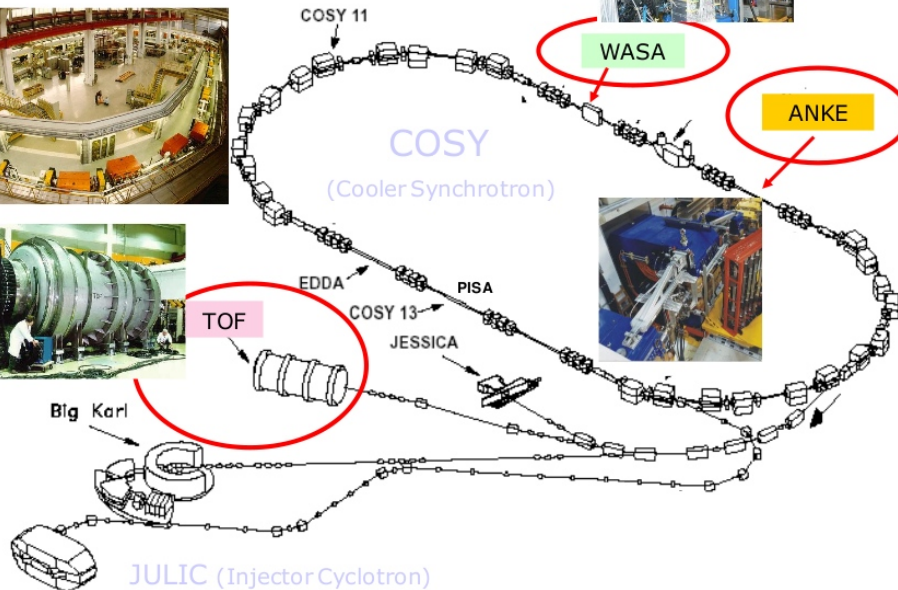
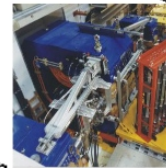
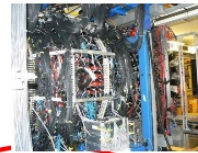
WASA Proposal 1987: key experiments: $\pi^0, \eta \rightarrow e^+e^-$



CELSIUS <2005

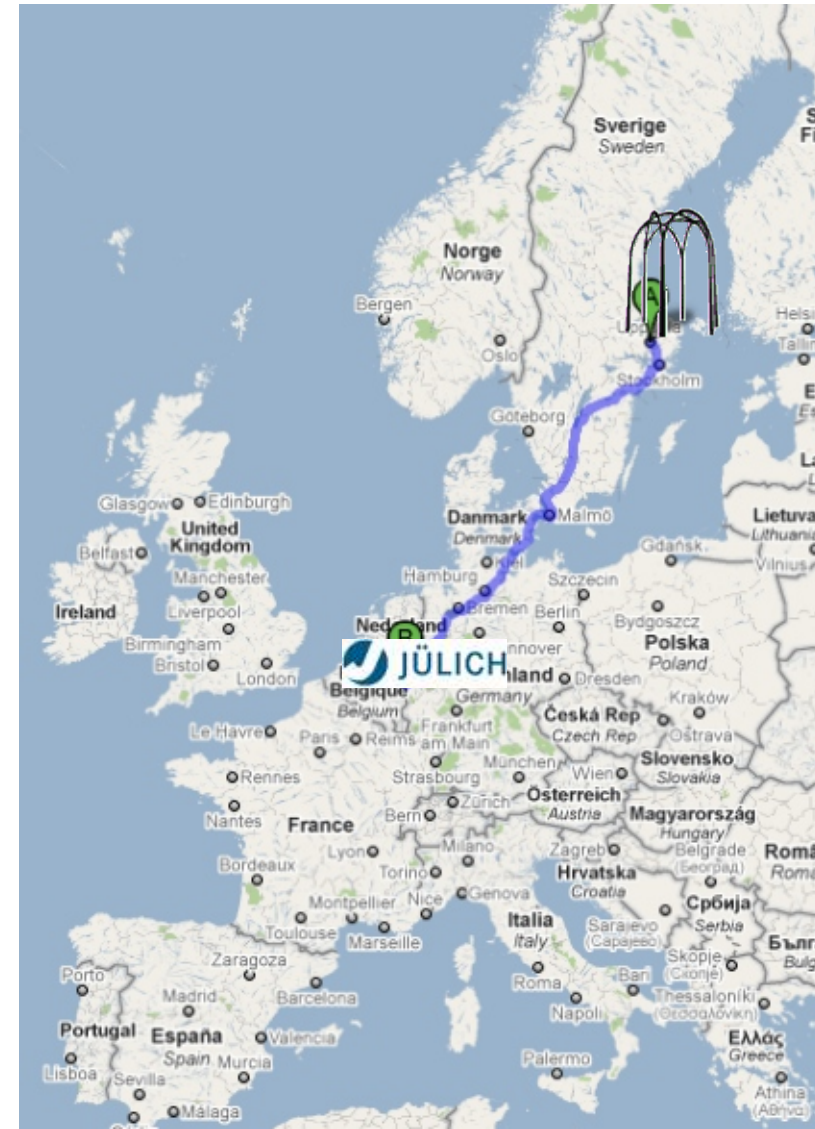


COSY >2007



Schematic overview COSY Facility (FZ-Jülich)

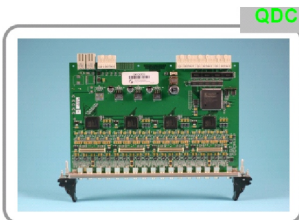
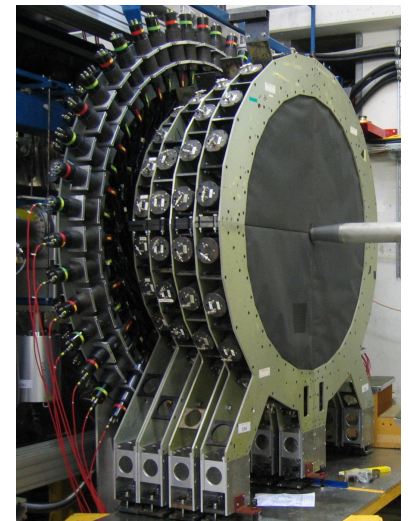
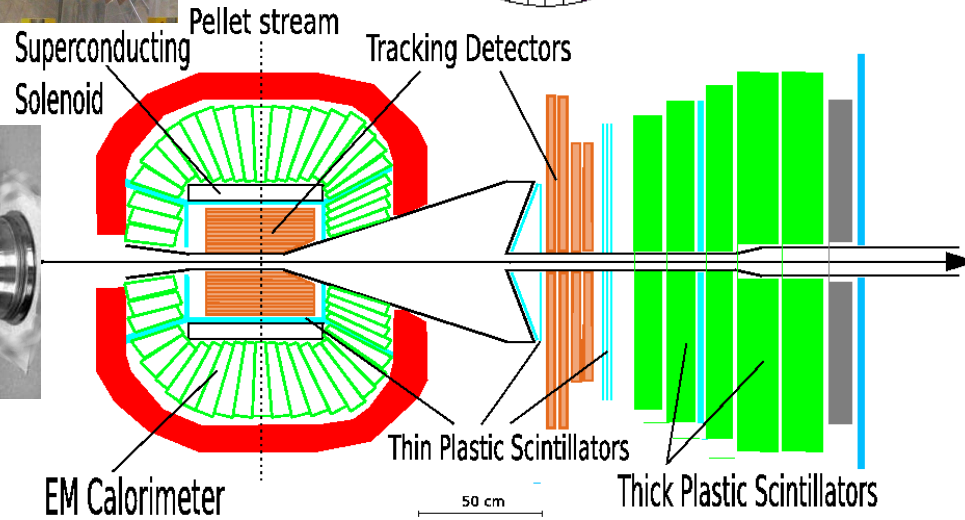
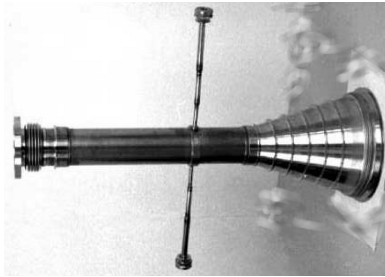
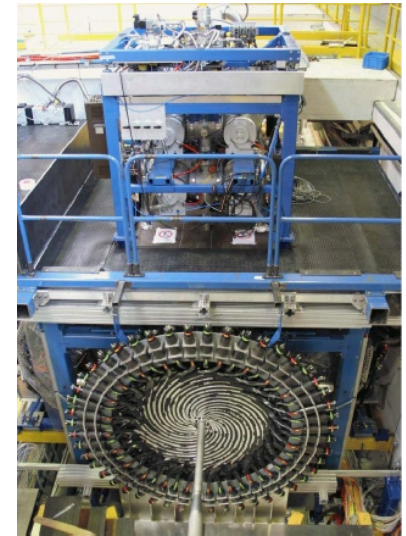
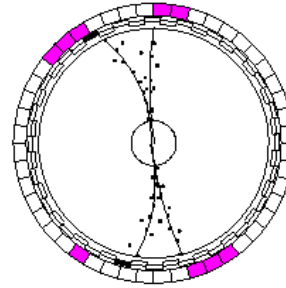
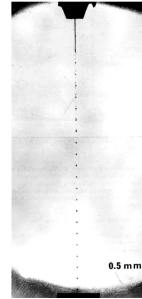
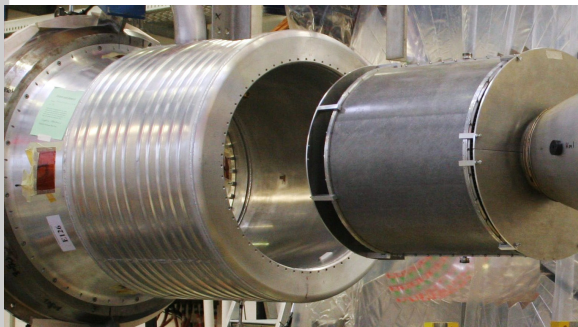
Recent results from Experiments at COSY, HADRON2009, 4/12/09



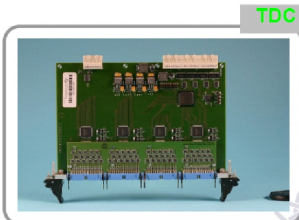


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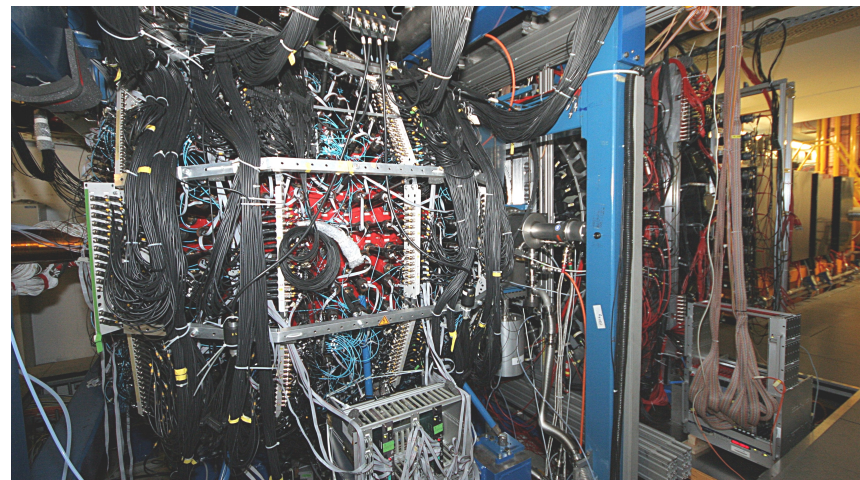
WASA detector



QDC



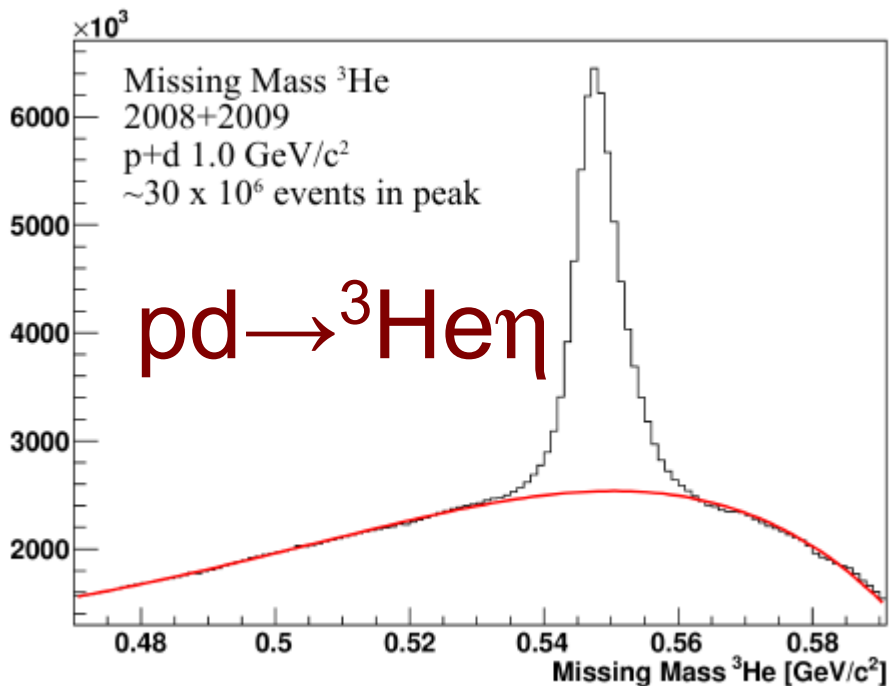
TDC



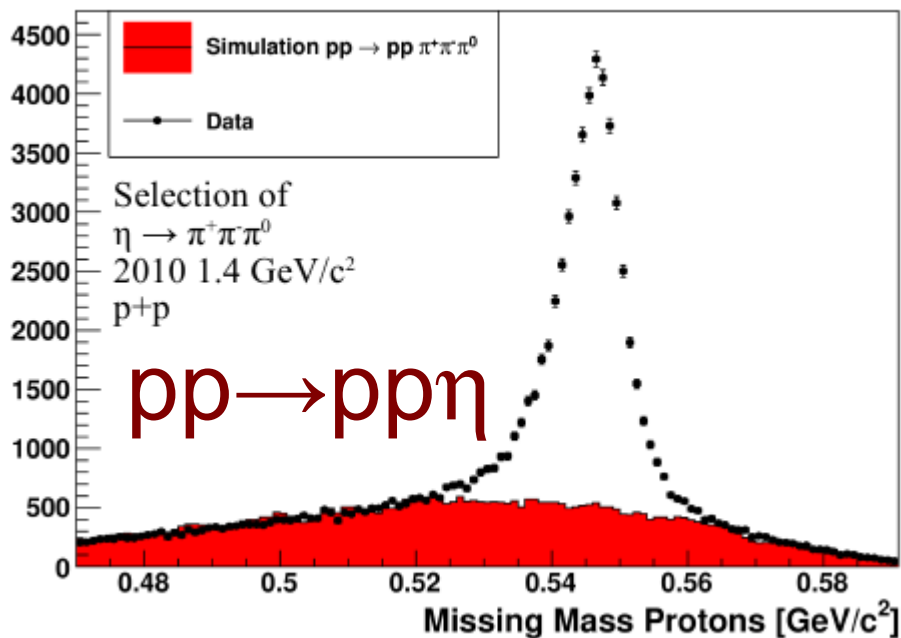
NIM A594,339



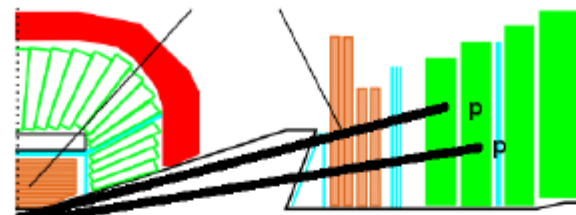
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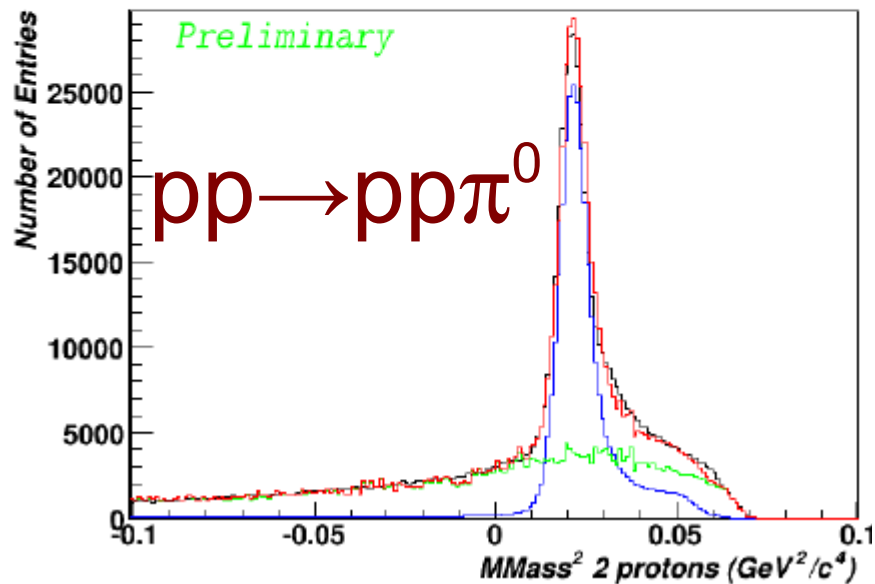
$$\text{Missing Mass} = \sqrt{(E_{\text{in}} - E_{\text{out}})^2 - (P_{\text{in}} - P_{\text{out}})^2}$$



Meson tagging



2 FD protons



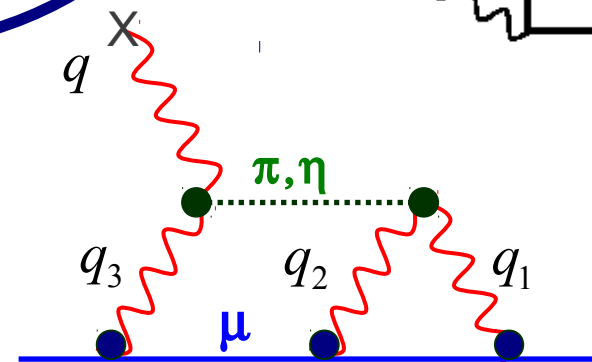
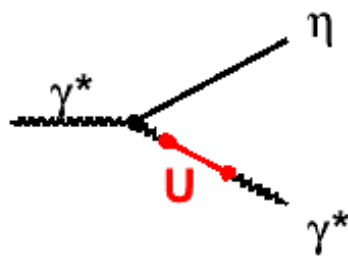
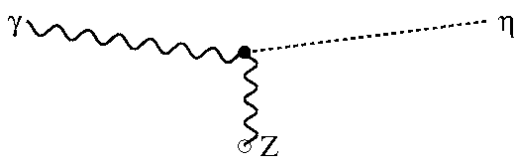
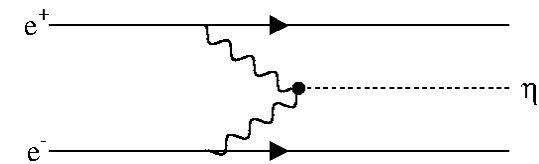
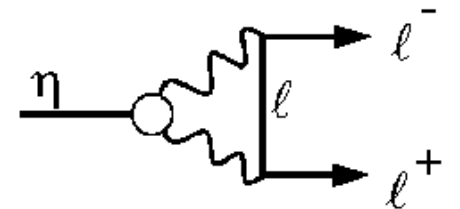
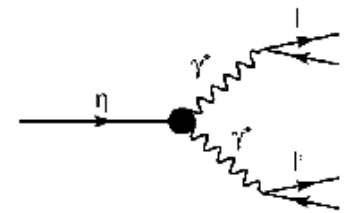
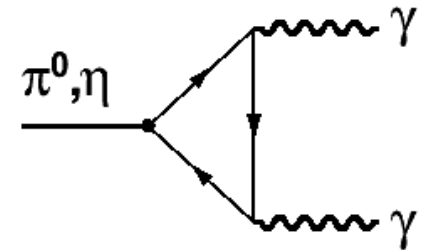
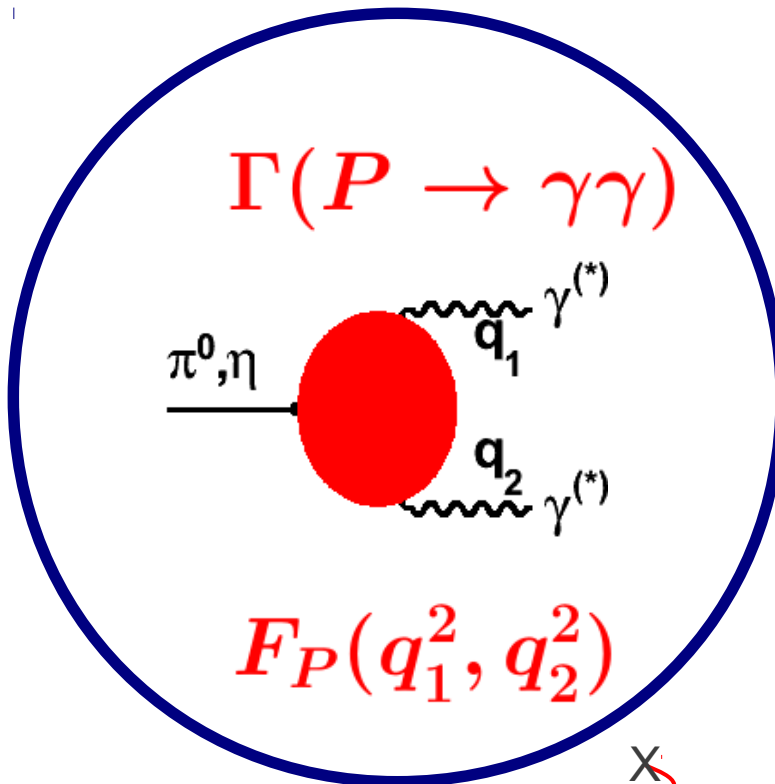
Meson Transition Form Factors (TFF)

Low energy QCD

Chiral anomaly

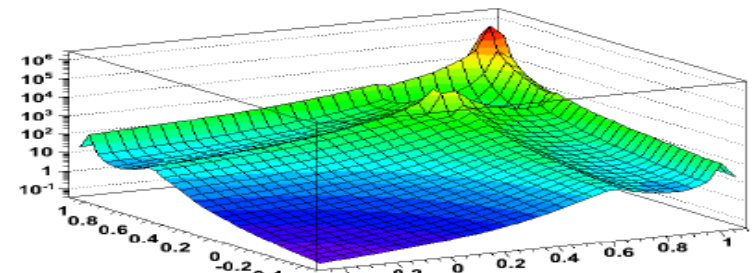
SM contribution to a_μ

U boson



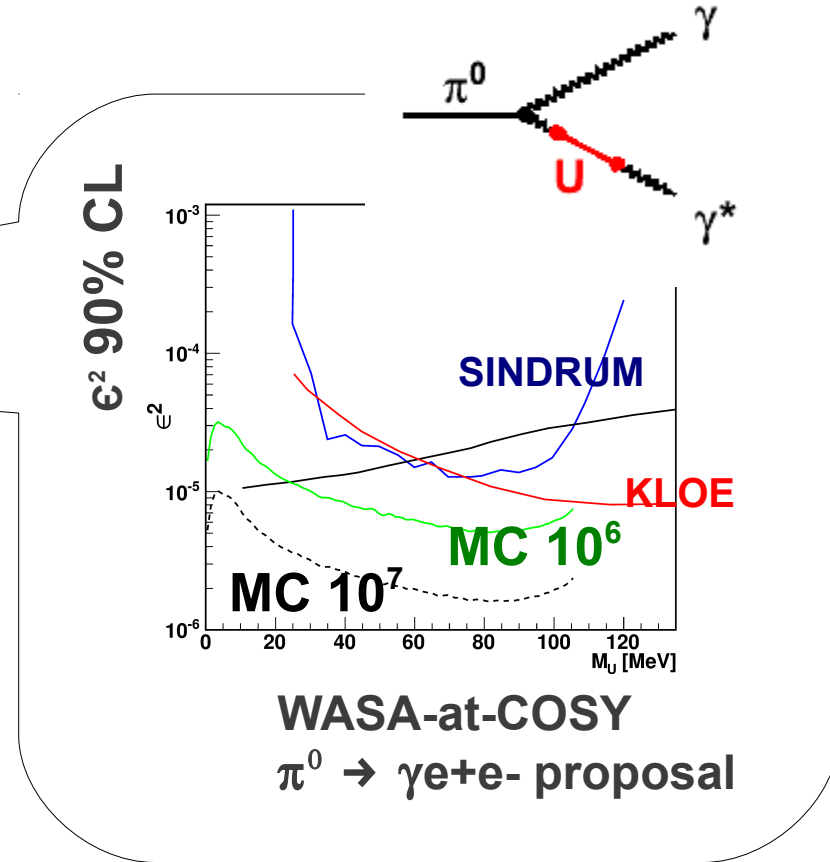
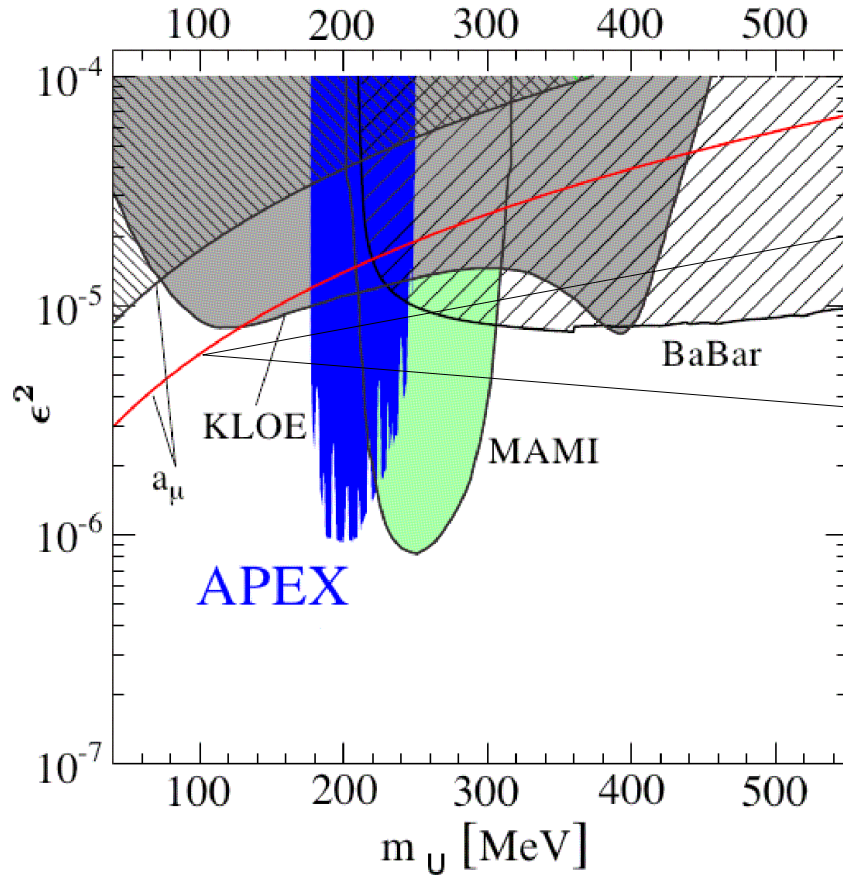
Workshop on Meson
Transition Form Factors

May 29-30, 2012 in Cracow, Poland





Dark photon searches



DARK2012
Dark Forces at Accelerators

16th - 19th, October 2012

Laboratori Nazionali di Frascati, INFN
Frascati (Rome), Italy





- 2010 run $pp \rightarrow pp\pi^0$ at 550 MeV
- ca 10^6 $\pi^0 \rightarrow e^+e^-\gamma$ events
- WASA was designed to measure $\pi^0 \rightarrow e^+e^-$ (1987)
 $pp \rightarrow pp\pi^0$ below 2π threshold ($T_p = 579$ MeV)

Background:

- $\pi^0 \rightarrow e^+e^-\gamma$ (γ not detected)
- $\pi^0 \rightarrow \gamma\gamma$ (γ conversion in detector material)
- pp virtual bremsstrahlung $pp \rightarrow ppe^+e^-$

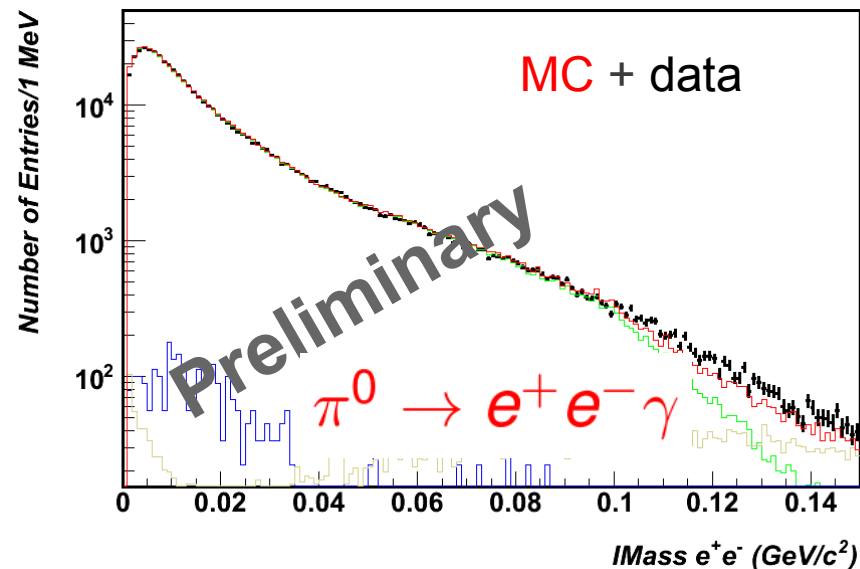
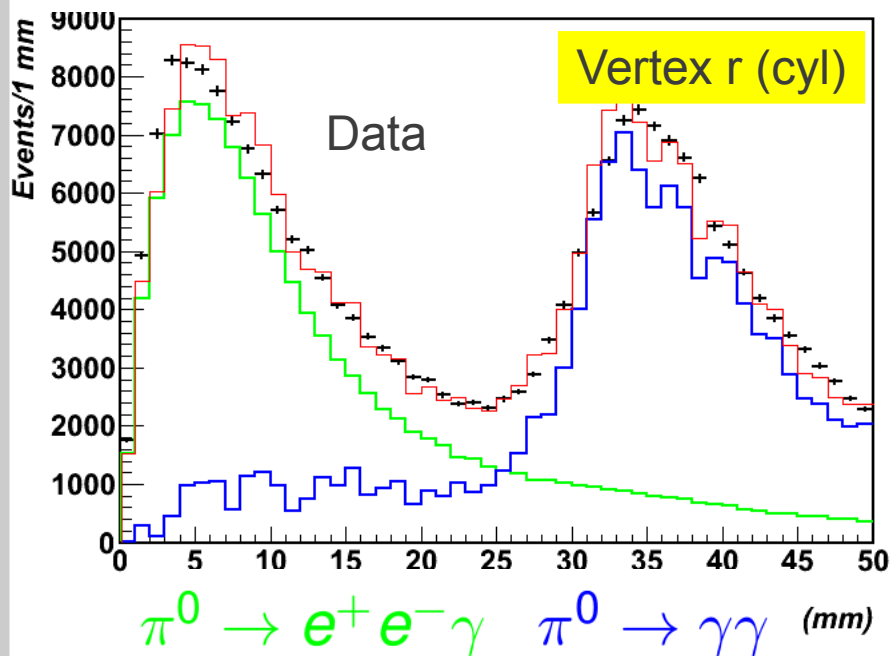
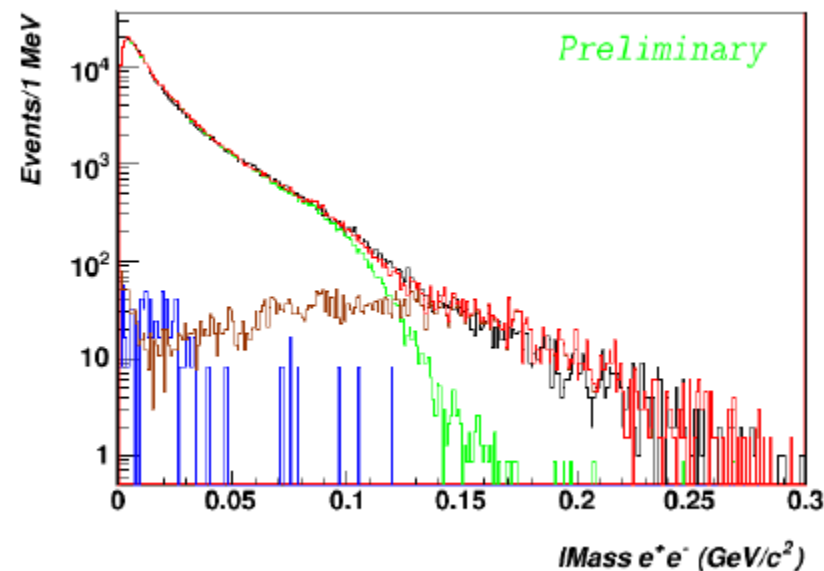
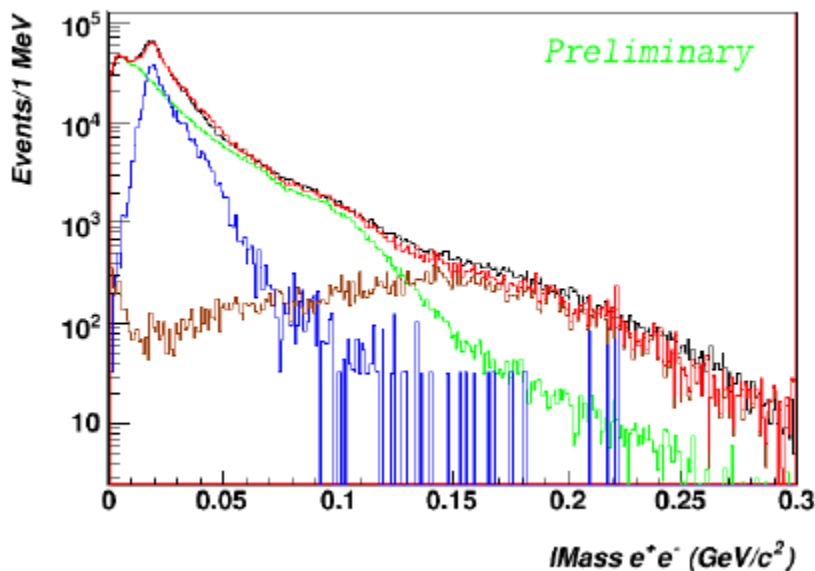


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Analysis: $\pi^0 \rightarrow \gamma e^+ e^-$

Vertex $r < 20$ mm + PID



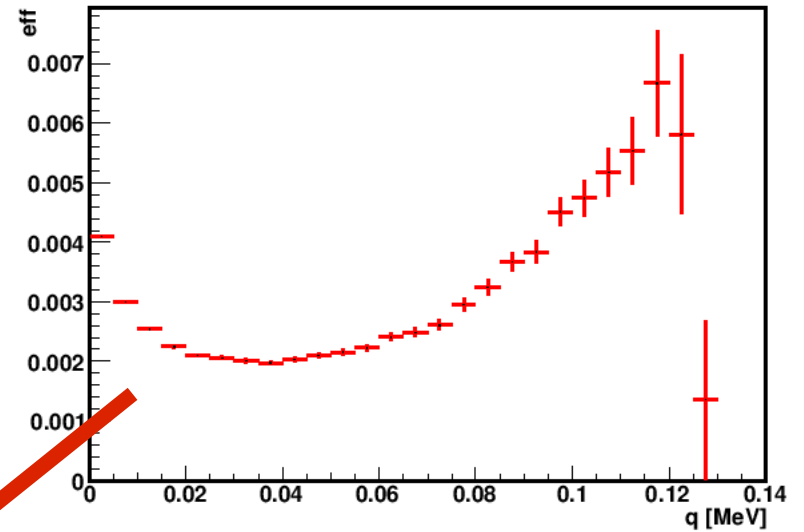
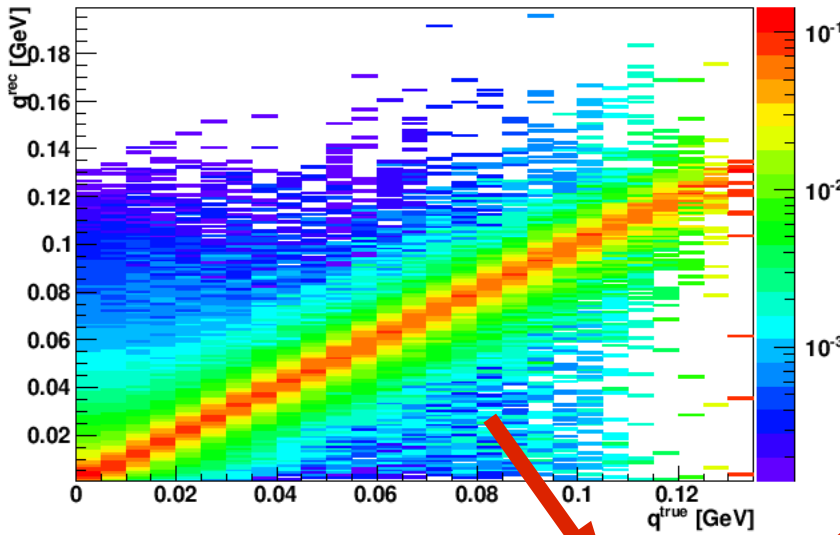
Extraction of: $\pi^0 \rightarrow \gamma U \rightarrow \gamma e^+ e^-$



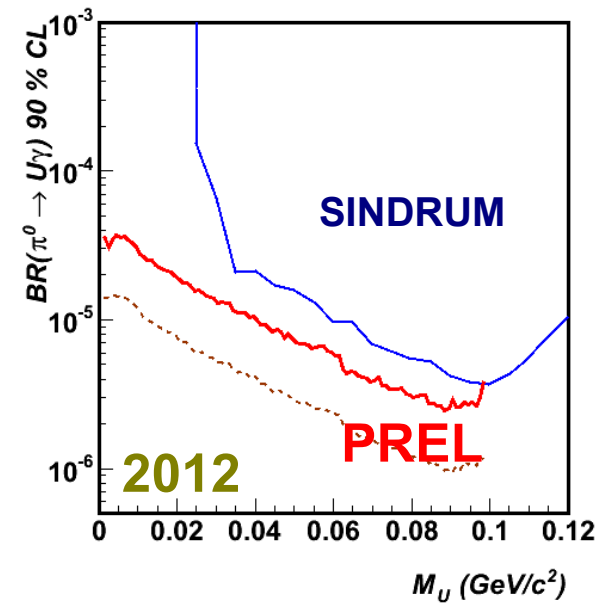
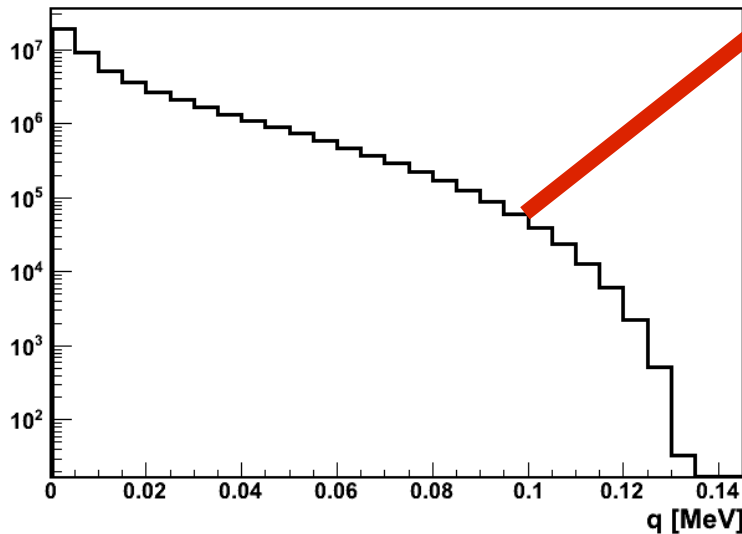
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Smearing matrix

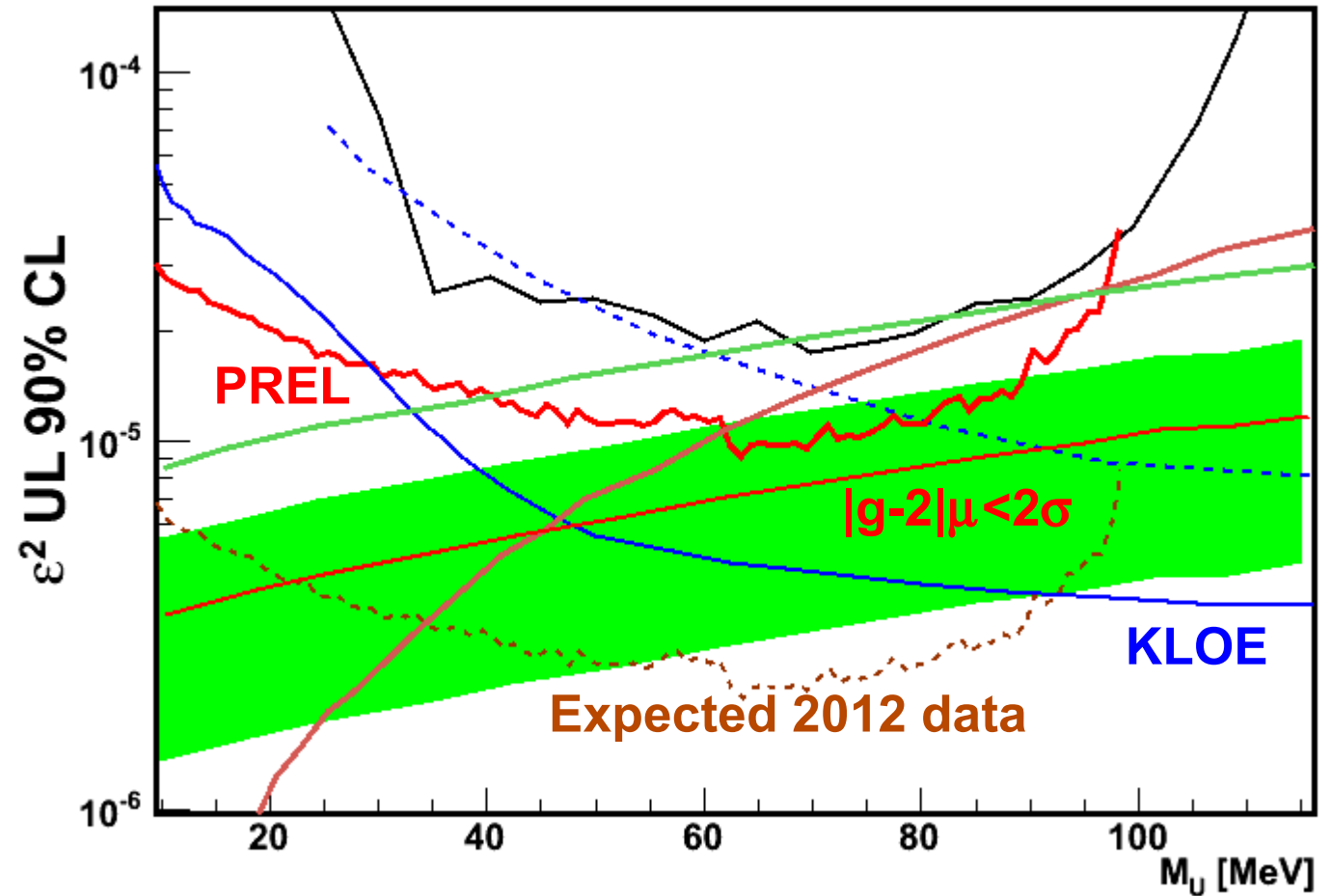


$$N_i^d / N_{Tot} = \sum_j S_{ij} \epsilon_j \nu_j (\pi^0 \rightarrow e^+ e^- \gamma) + S_{ik} \epsilon_k \beta_k$$



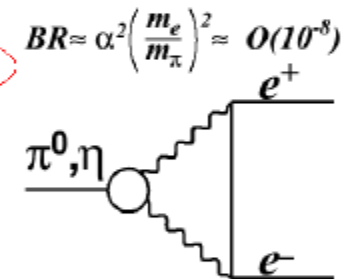
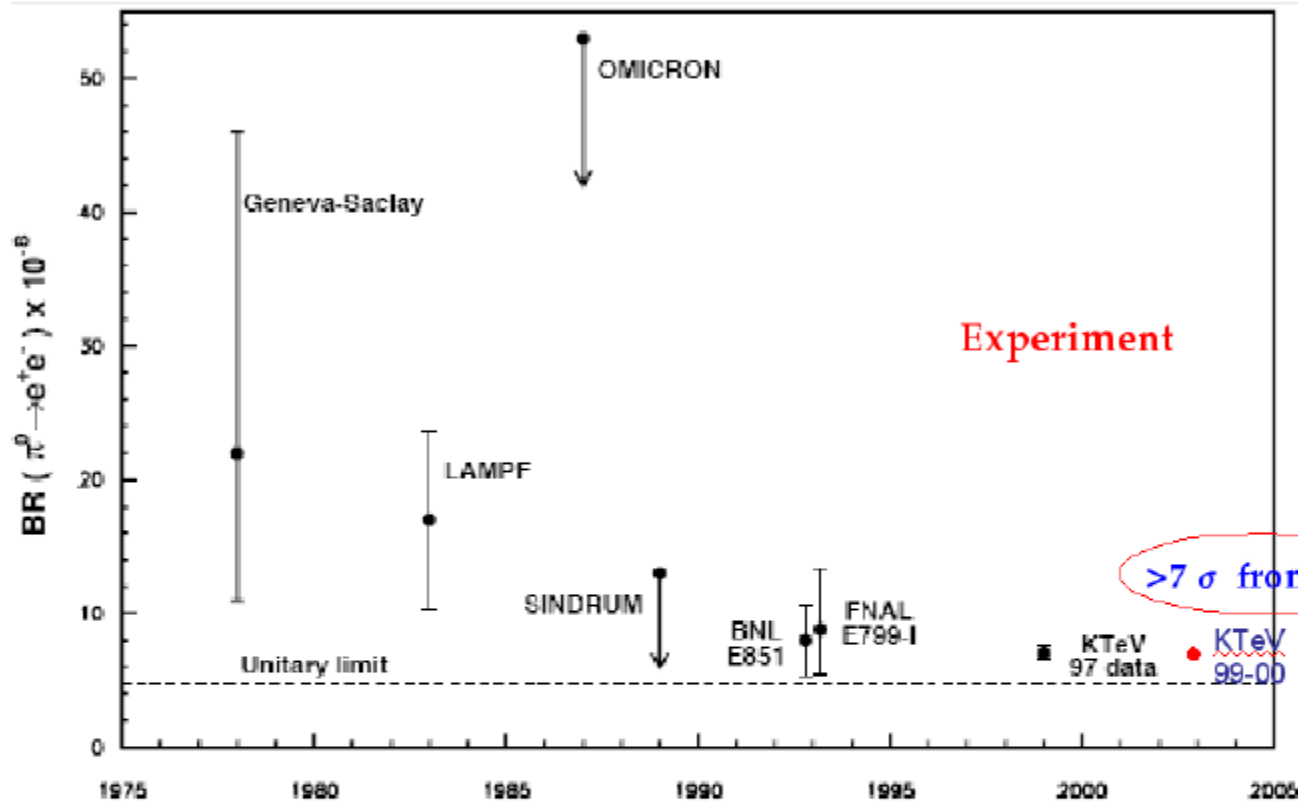


$$\frac{\Gamma(\pi^0 \rightarrow \gamma U)}{\Gamma(\pi^0 \rightarrow \gamma \gamma)} = \epsilon^2 |F_{\pi^0}(m_U^2)|^2 \left(1 - \frac{m_U^2}{m_{\pi^0}^2}\right)^3$$





History of $\pi^0 \rightarrow e^+ e^-$ measurements



- Unitary bound (model independent) $BR \geq 4.75 \cdot 10^{-8}$
- Experiment: KTeV (794 events from $K_L \rightarrow 3\pi^0$):
 $BR(\pi^0 \rightarrow e^+ e^-) = (6.44 \pm 0.25_{stat} \pm 0.22_{syst}) \times 10^{-8}$
 $BR_{no-rad}(\pi^0 \rightarrow e^+ e^-) = (7.48 \pm 0.29_{stat} \pm 0.25_{syst}) \times 10^{-8}$

$\pi^0, \eta \rightarrow l^+ l^-$

$$BR \approx \alpha^2 \left(\frac{m_e}{m_\pi} \right)^2 \approx O(10^{-8})$$

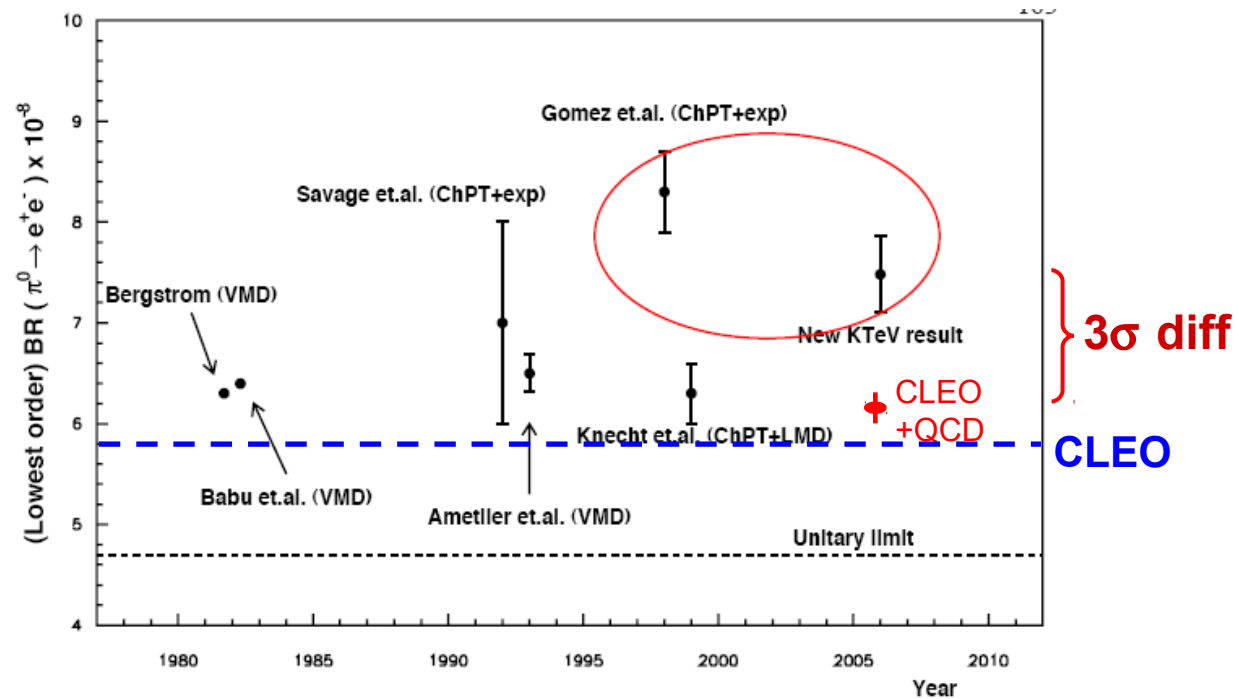
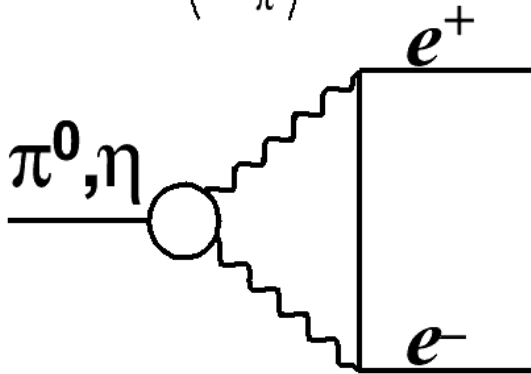


TABLE II. Values of the branchings $B(P \rightarrow l^+ l^-)$ obtained in our approach and compared with the available experimental results.

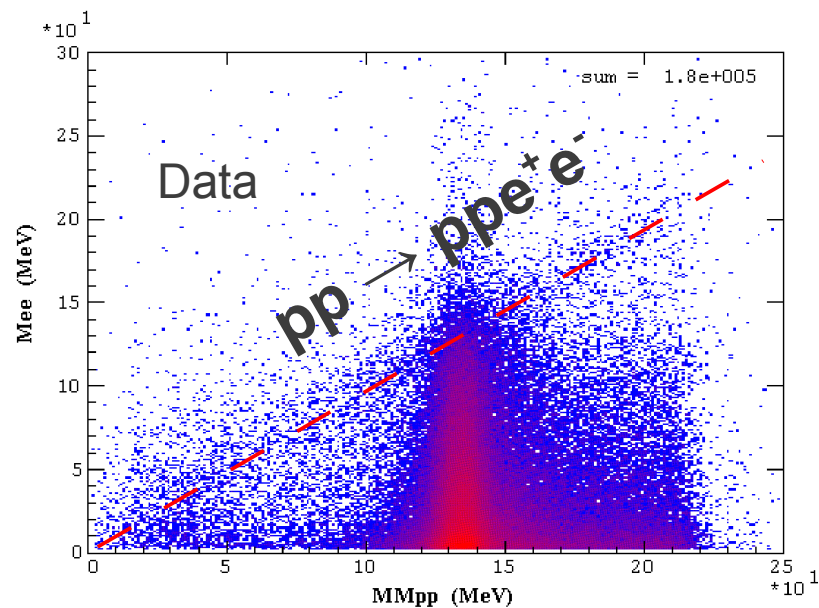
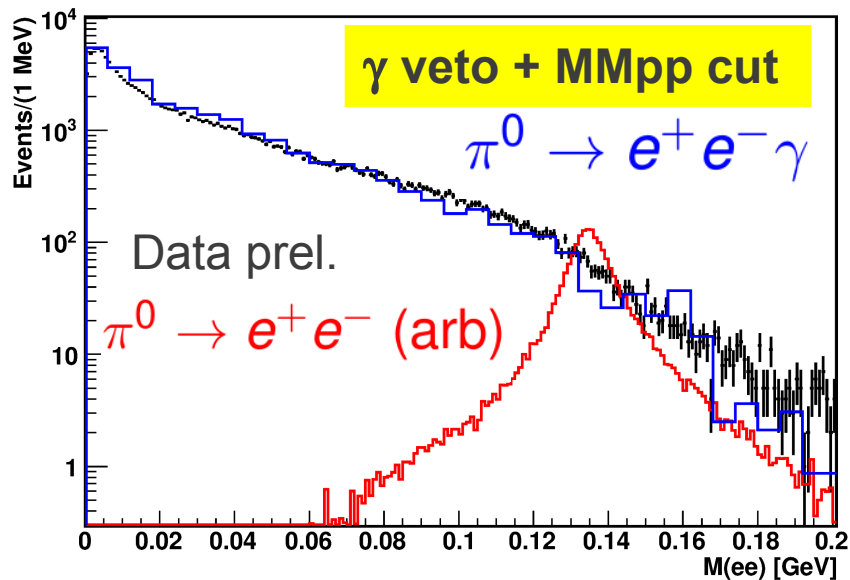
B	Unitary bound	CLEO bound	CLEO + OPE	Experiment
$B(\pi^0 \rightarrow e^+ e^-) \times 10^8$	≥ 4.69	$\geq 5.85 \pm 0.03$	6.23 ± 0.09	7.49 ± 0.38 [1]
$B(\eta \rightarrow \mu^+ \mu^-) \times 10^6$	≥ 4.36	$\leq 6.23 \pm 0.12$	5.11 ± 0.20	5.8 ± 0.8 [7,32]
$B(\eta \rightarrow e^+ e^-) \times 10^9$	≥ 1.78	$\geq 4.33 \pm 0.02$	4.60 ± 0.06	...



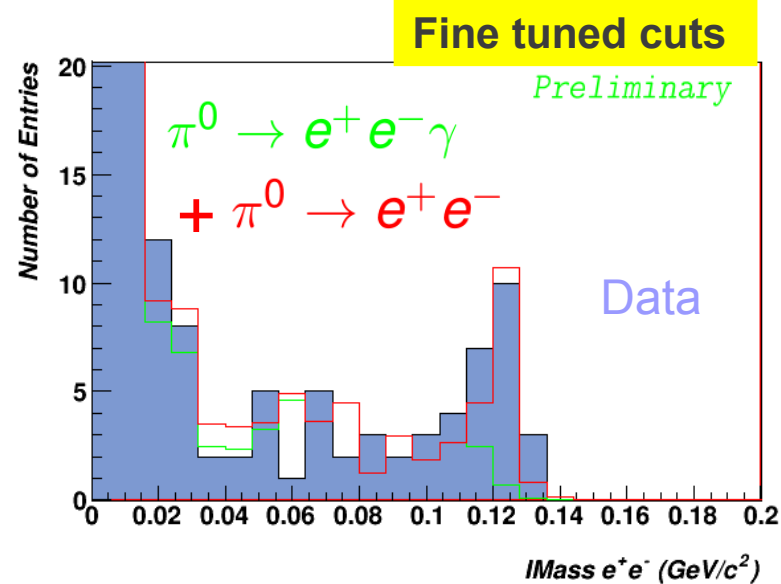
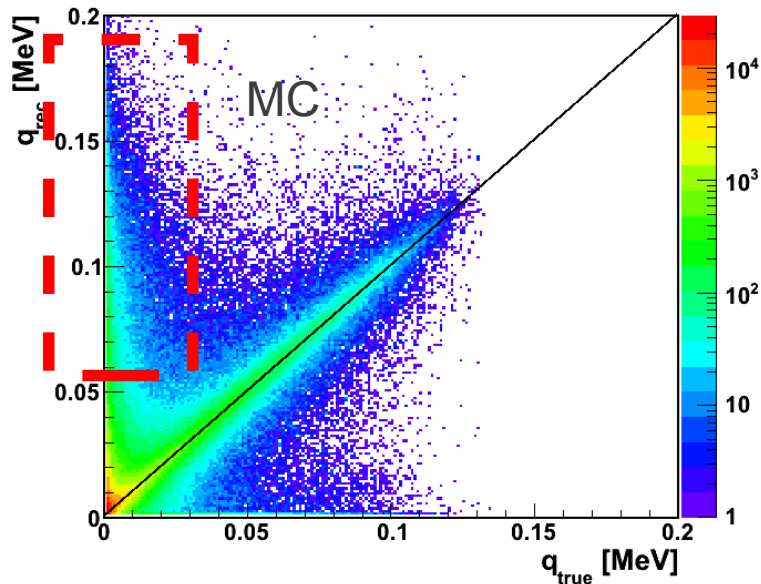
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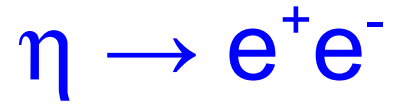


Analysis: $\pi^0 \rightarrow e^+e^-$



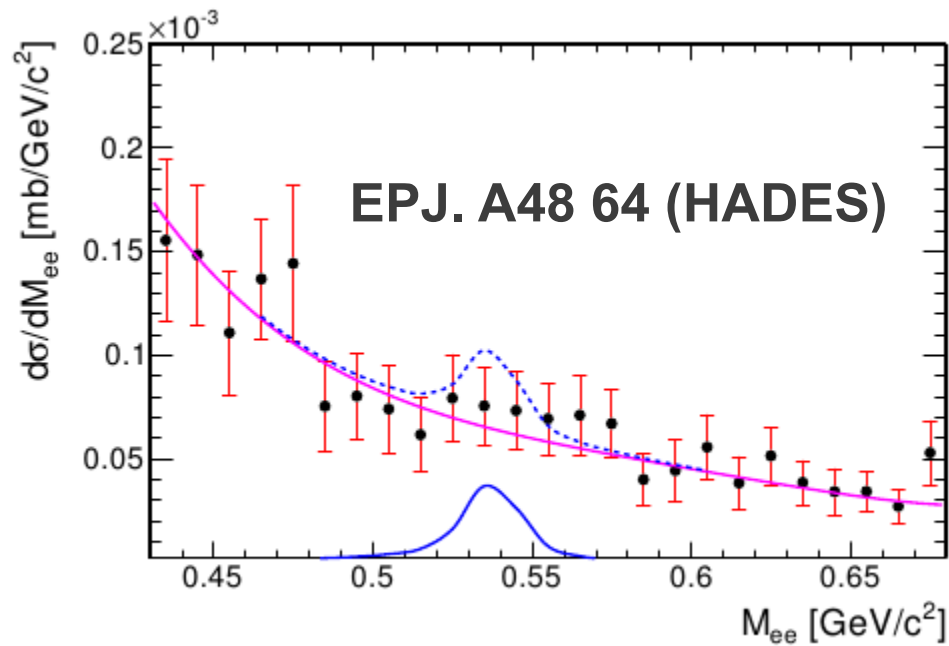
$$\pi^0 \rightarrow e^+e^- \gamma$$





$$\Gamma(e^+e^-) / \Gamma_{\text{total}}$$

VALUE	CL%	DOCUMENT ID	TECN	COMMENT
$<5.6 \times 10^{-6}$	90	¹ AGAKISHIEV	12A SPEC	$p p \rightarrow \eta + X$
* * * We do not use the following data for averages, fits, limits, etc. * * *				
$<2.7 \times 10^{-5}$	90	BERLOWSKI	08 WASA	$p d \rightarrow {}^3\text{He} \eta$
$<0.77 \times 10^{-4}$	90	BROWDER	97B CLE2	$e^+e^- \sim 10.5 \text{ GeV}$
$<2 \times 10^{-4}$	90	WHITE	96 SPEC	$p d \rightarrow \eta {}^3\text{He}$
$<3 \times 10^{-4}$	90	DAVIES	74 RVUE	Uses ESTEN 1967



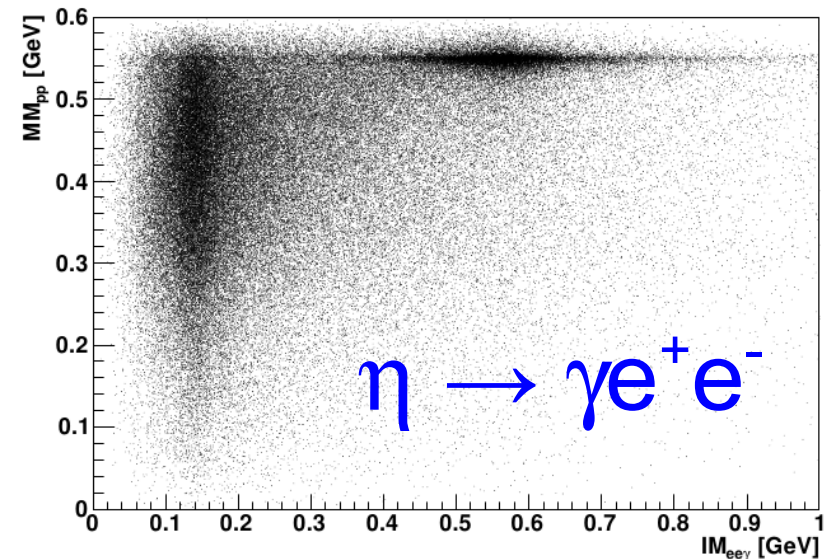
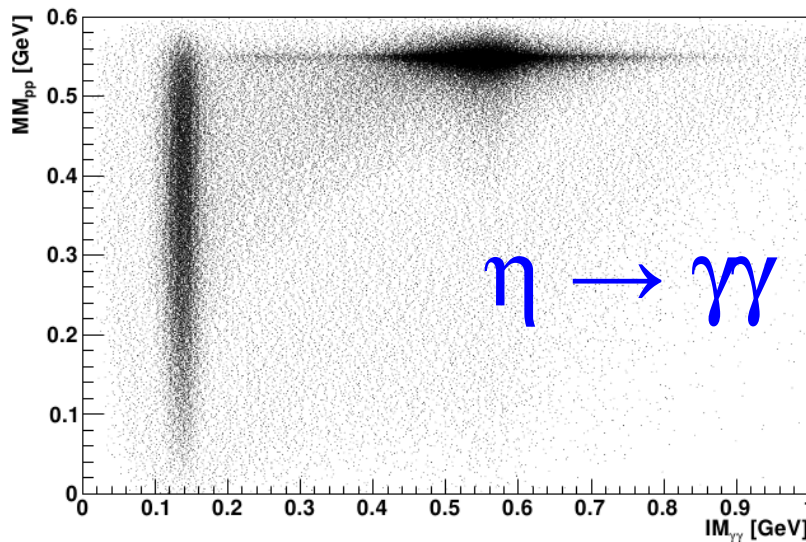


η decays at WASA

- $pd \rightarrow {}^3\text{He}\eta$ 3×10^7 events
- $pp \rightarrow pp\eta$ $> 5 \times 10^8$ events
- Background for $\eta \rightarrow e^+e^-$:
 - $\eta \rightarrow e^+e^-\gamma, \eta \rightarrow \gamma\gamma$
 - pp virtual bremsstrahlung $pp \rightarrow ppe^+e^-$
 - $pp \rightarrow pp\pi^+\pi^-$

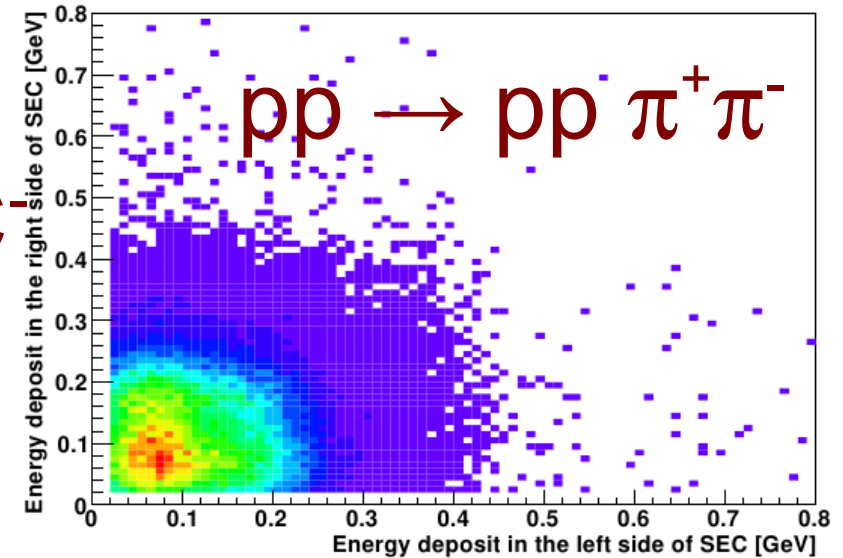
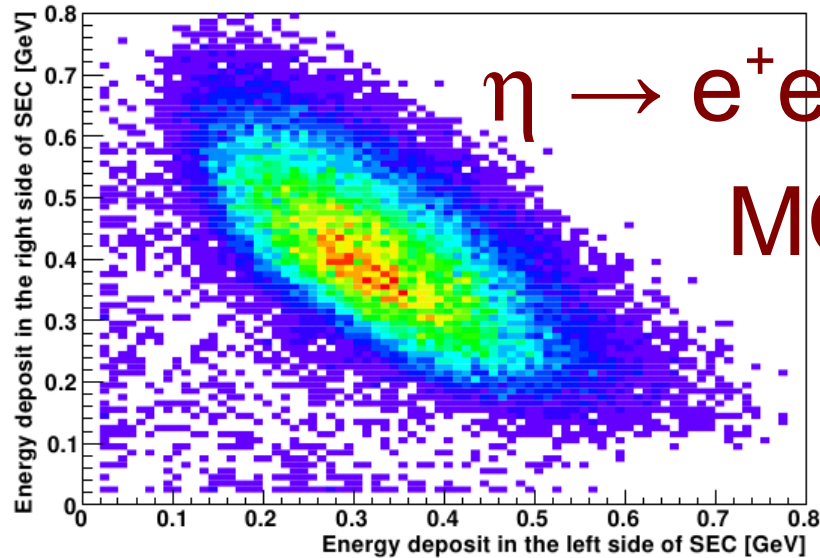
Finalized analysis for ca 3×10^7

Analysis (PhD): M. Berłowski, D. Coderre

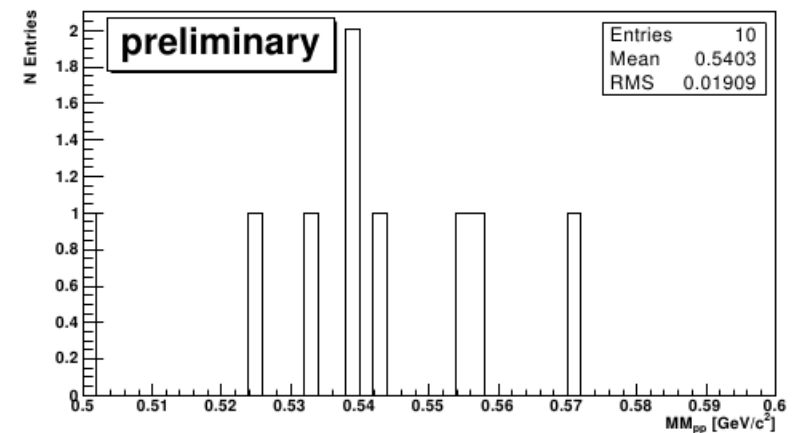
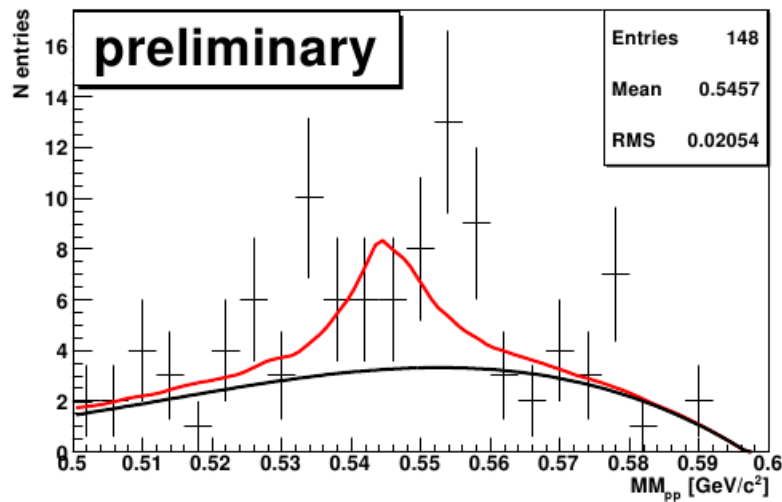




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DATA



$$BR_{limit} = 4.6 \times 10^{-6} \text{ at } CL 90\% \text{ (preliminary)}$$

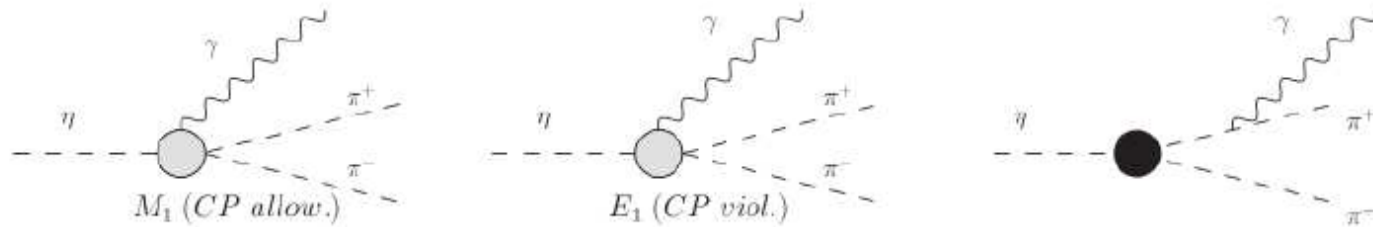


CP test in $\eta \rightarrow \pi^+ \pi^- e^+ e^-$

- $\eta \rightarrow \pi^+ \pi^- \gamma^{(*)}$ (γ polarization)

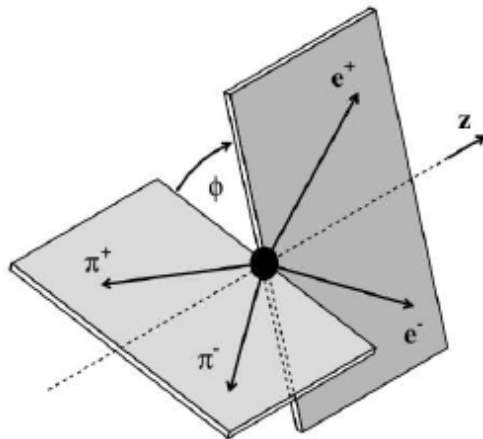
Geng, Ng, Wu MPL A17:1489(02)

- not constrained by d_n



- Angle between decay planes in $\eta \rightarrow \pi^+ \pi^- e^+ e^-$

Gao MPL A17:1583(02)



$$A \equiv \frac{N(0 < \phi < 90) - N(90 < \phi < 180)}{N(0 < \phi < 180)}$$

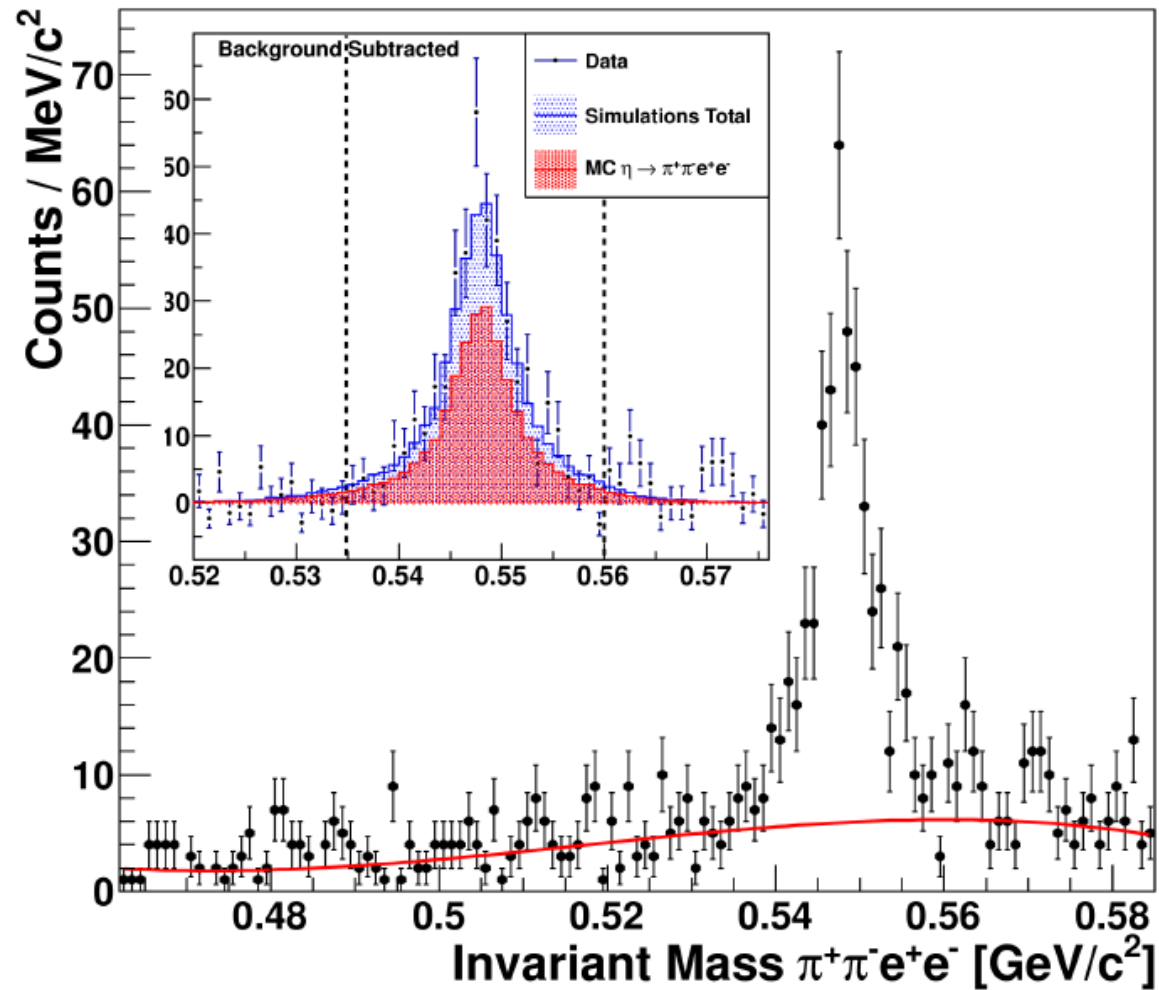
$$A \leq 0.02 \text{ (from } \eta \rightarrow \pi^+ \pi^- \text{)}$$

$$A = (-0.6 \pm 2.5 \pm 1.8) \times 10^{-2}$$

KLOE PLB675,283(09)



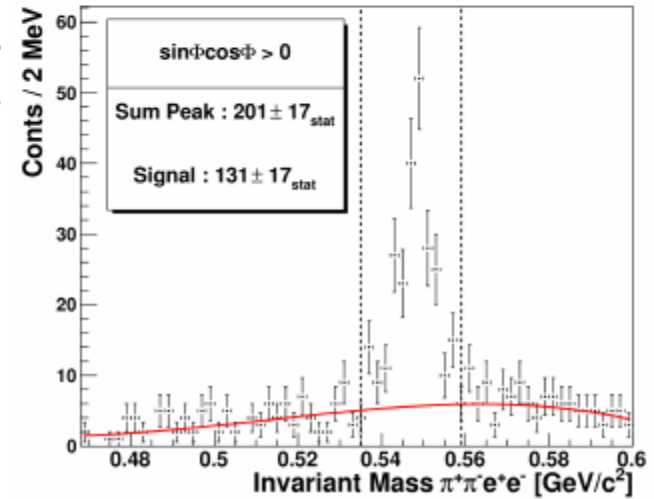
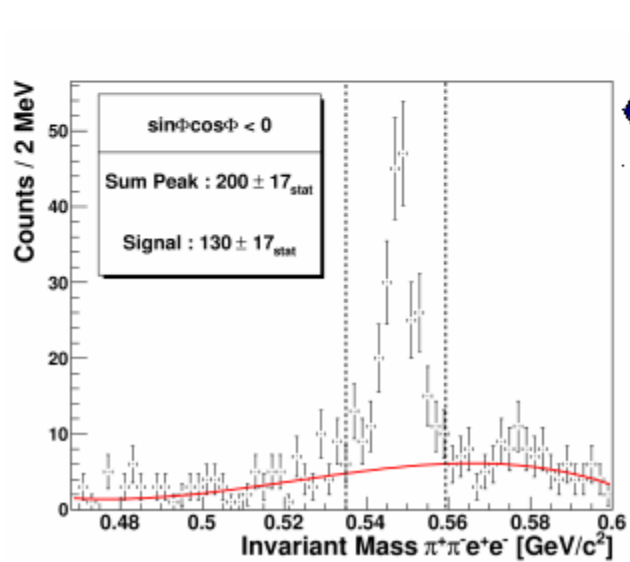
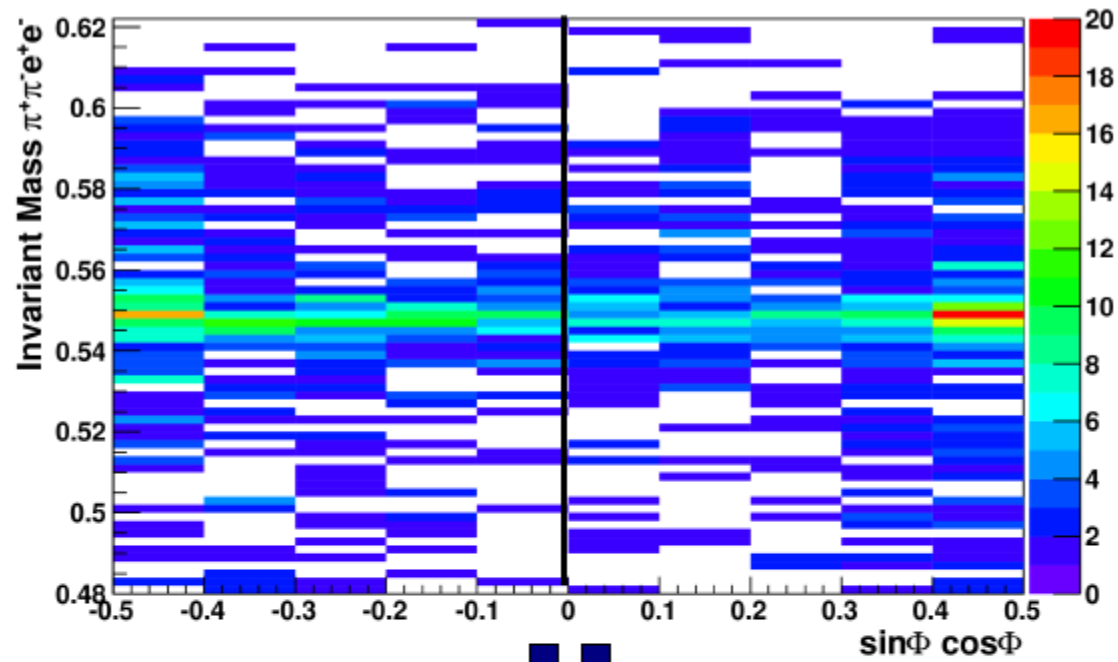
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$$\text{BR}(\eta \rightarrow \pi^+\pi^-e^+e^-) = (3.10 \pm 0.27_{\text{stat}} \pm 0.22_{\text{sys}}) \times 10^{-4}$$



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$$A_{\Phi} = 0.3 \pm 9.0_{\text{stat}} \times 10^{-2} \quad \textit{Preliminary}$$



Conclusions

- + World largest $\pi^0 \rightarrow e^+ e^- \gamma$ data sample ca 10^7 events
- + $> 5 \times 10^8$ η meson decays
- ⇒ Transition formfactor studies, CHPT,...
- ⇒ Limits on ϵ^2 vs M_U , tests of discrete symmetries
 - Presented results based on 10% of the collected data

Analysis (PhD): C-O. Gullström, M. Berłowski, D. Coderre

Matias Costa for The New York Times

